

Blockchain in the Construction Industry

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ABSTRACT

Blockchain is a distributed database that allows for secure, transparent, and tamper-proof transactions in its simplest form. It is a system that tracks transactions across a peer-to-peer network. Its main defining feature is decentralization. It is poised to transform the entire foundation of the construction sector, which is on the verge of a technological revolution. It can solve the problems rooted in payment systems, collaboration, documents in the construction industry. This paper explores how blockchain technology could potentially change the construction industry for the better.

KEYWORDS: *blockchain, construction industry*

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INTRODUCTION

Blockchain is a system that tracks transactions across a peer-to-peer network. In some cases, these transactions are made via either cryptocurrency or Bitcoin. Blockchain technology (BCT) is a revolutionary tool used to record transactions and link them together to form a “chain” that’s known as a distributed ledger. It was introduced a decade ago as the underlying technology behind Bitcoin. BCT application has been extended since its first appearance in 2008 by Satoshi Nakamoto, from financial services to agricultural supply chains. Blockchain has the potential to revolutionize many different industries, including construction. Blockchain in construction, which was initially developed to support cryptocurrencies, has transcended its intended use and found use in a variety of industries, offering increased transparency, improved security, and simplified procedures. Figure 1 shows the symbol of blockchain [1].

The construction industry happens to be one of the most critical industries in the world. We rely on construction workers to build everything from roads and bridges to hospitals and schools. Yet, the

construction industry has traditionally been very slow to adopt new technologies. Integrating recent technologies such as the internet of things (IoT), artificial intelligence, and blockchain creates the potential for overcoming many limitations within the construction industry. Considering the challenges faced in the construction industry, including schedule delays, cost overruns, and quality control issues, blockchain can potentially revolutionize project planning, design, execution, and long-term maintenance, thereby improving transparency, efficiency, and collaboration in the construction process. Figure 2 shows a typical construction site [2], while Figure 3 shows some construction workers [2].

WHAT IS BLOCKCHAIN?

Blockchain, a type of distributed digital ledger technology (DLT), is a relatively new and exciting way of recording transactions in the digital age. It is a decentralized and distributed digital ledger technology that securely records and verifies transactions across multiple computers or nodes in a network. Basically, it is a chain of blocks

in which each block contains a list of transactions. The blockchain technology was created as the foundational basis for Bitcoin – a digital currency in which secure peer-to-peer transactions occur over the Internet. It is expected that the spending on blockchain solutions worldwide would grow from 4.5 billion USD (2020) to an estimated value of 19 billion USD by 2024 [3].

Originally developed as the accounting method for the virtual currency Bitcoin, Blockchains are appearing in a variety of commercial applications today. Blockchain technology is a type of distributed digital ledger that uses encryption to make entries permanent and tamper-proof and can be programmed to record financial transactions. It is used for secure transfer of money, assets, and information via a computer network such as the Internet without requiring a third-party intermediary. It is now being adopted across financial and non-financial sectors. As a catalyst for change, the Blockchain technology is going to change the business world and financial matters in major ways.

The first Blockchain was conceived in 2008 by an anonymous person or group known as Satoshi Nakamoto, who published a white paper introducing the concept of a peer-to-peer electronic cash system he called Bitcoin [4,5]. Bitcoin and Ethereum are the first two mainstream blockchains. Other modern blockchains include Namecoin, Peercoin, Ether, and Litecoin. Figure 4 shows different components of blockchain [6].

Blockchain combines existing technologies such as distributed digital ledgers, encryption, immutable records management, asset tokenization and decentralized governance to capture and record information that participants in a network need to interact and transact. As illustrated in Figure 5, a complete blockchain incorporates all the following five elements [7]:

- *Distribution*: Digital assets are distributed, not copied or transferred. A protocol establishes a set of rules in the form of distributed mathematical computations that ensures the integrity of the data exchanged among a large number of computing devices without going through a trusted third party. A centralized architecture presents several issues including a single point of failure and problems of scalability.
- *Encryption*: BC uses technologies such as public and private keys to record data securely and semi-anonymously. Completed transactions are cryptographically signed, time-stamped, and sequentially added to the ledger.

- *Immutability*: The blockchain was designed so these transactions are immutable, i.e. they cannot be deleted. No entity can modify the transaction records. Thus, Blockchains are secure and meddle-free by design. Data can be distributed, but not copied.
- *Tokenization*: Value is exchanged in the form of tokens, which can represent a wide variety of asset types, including monetary assets, units of data or user identities.
- *Decentralization*: No single entity controls a majority of the nodes or dictates the rules. A consensus mechanism verifies and approves transactions, eliminating the need for a central intermediary to govern the network.

Bitcoin and its underlying blockchain technology increasingly impact all facets of society. Bitcoin's status as digital gold is merely the tip of this technology. Figure 6 shows Bitcoin [8], while Figure 7 shows how blockchain works [9]. Although blockchain technology will for all time be associated with Bitcoin due to their common genesis, it has broader applications. Cryptocurrency will increasingly become a factor in family law issues as well.

A blockchain is a tamper-proof, distributed database that stores blocks of information for cryptographically bound transactions via peer-to-peer networks. At the heart of blockchain's functionality is cryptographic hashing. Each block in a blockchain contains a cryptographic hash of the previous block, creating an immutable chain of blocks. If anyone attempts to tamper with the data in a block, it would alter the block's hash. This would disrupt the entire chain, making it virtually impossible to manipulate. The security feature ensures data integrity and prevents unauthorized changes [10].

In a nutshell, blockchain technology involves three basic concepts [11]: (1) It is a system for recording a series of data items (such as transactions between parties); (2) It uses cryptography to make it difficult to tamper with past entries; (3) It has an agreed process for storing copies of the ledger and adding new entries (also called a consensus protocol).

Blockchain is a novel decentralized infrastructure and distributed computing paradigm that uses a chained data structure for verification, storage, and distributed consensus algorithms to generate and update data. Decentralization is a key feature of blockchain technology, which refers to the distribution of power and decision-making across a network of nodes or participants rather than being controlled by a central authority or system. Decentralization provides

robustness while eliminating many-to-one traffic flows to avoid delays and single points of failure. Figure 8 shows the decentralized property of blockchain [9]. The advantages of decentralized property of blockchain network include the following [9]:

- The decentralized property of blockchain makes it less prone to failure and more expensive for hackers to attack the network.
- There is no third-party involvement; therefore, there is no added risk.
- Every change made in the network is traceable and concrete.
- Users maintain full autonomy of their properties and are not dependent on third parties to maintain and manage their assets.
- It provides enhanced security.

BLOCKCHAIN IN CONSTRUCTION

Blockchain in construction means applying blockchain technology in the construction process. The use of blockchain in construction holds enormous promise for revolutionizing the way construction projects are planned, carried out, and controlled. A blockchain in construction is fundamentally a distributed, unchangeable digital ledger that securely and openly records transactions and other data. Blockchain in construction has the ability to transform supply chain management, automate contract execution, guarantee document authenticity, and promote effective stakeholder engagement because of its decentralized and transparent nature. You can use blockchain in the construction industry to modernize project management, track supply chains, and handle financial transactions. Figure 9 shows blockchain in construction [12].

Although blockchain as a technology has been around for some time, the very idea of integrating it into construction is new. Construction is one of several industries that blockchain technology has the potential to disrupt. With its built-in attributes of transparency, security, and decentralization, blockchain can help the construction industry overcome significant obstacles, increase productivity, and simplify procedures.

APPLICATIONS OF BLOCKCHAIN IN PHARMACEUTICAL

Blockchain technology is being used in the building industry, from quality control and supply chain management to document verification and project collaboration. BCT has vast potential applications in the construction industry, such as supply chain management, project bidding, contract management,

management of certifications and permits, transparency and traceability, supplier management, quality control, and certification, smart contracts and automation, streamlined payment processes, immutable contract execution, dispute resolution, document management and authentication, secure sharing and storage, digital signatures and timestamps, anti-fraud measures, project management, etc. Common areas of application include the following [2,13,14]:

- *Construction Payments:* Delayed payments are a frequent problem in the construction industry. By facilitating direct and secure peer-to-peer payments, blockchain-based payment systems can simplify financial transactions in the construction industry. Blockchain technology can be used to streamline construction payments. It is not uncommon for payments to be delayed by 30 days or more in the construction industry. This can create a lot of financial strain for construction companies, as they often have to borrow money to cover materials and labor costs. With blockchain technology, construction companies could receive payments almost instantly after completing a job. Blockchain improves the speed and efficiency of payment operations by doing away with middlemen and cutting transaction costs.
- *Construction Contracts:* Another way that blockchain technology could be used in construction is through smart contracts. Smart contracts are largely hailed as the future of the construction industry. Self-executing contracts with established rules and circumstances are known as smart contracts, another essential component of blockchain in construction. In other words, a smart contract is a digital contract that is stored on the blockchain. Smart contracts are autonomous contracts with set terms. They are immutable, meaning they cannot be altered or deleted. With a smart contract, the terms of the contract would be clearly defined and could not be changed. In construction projects, smart contracts based on BCT can enhance payment transparency, protect transaction histories, and provide secure access to information. Smart contracts boost efficiency by doing away with the need for middlemen and manual processing, which lowers costs, delays, and costs associated with project execution. Figure 10 shows the smart contract [15].
- *Project Management:* Blockchain technology can be used to improve project management in construction. Construction projects are often

complex and involve many different parties. With blockchain technology, all of the parties involved in a project would be able to view the digital ledger and see the progress made. This would help to improve communication and coordination between the different parties.

- *Procurement Process:* Blockchain technology can also be used to streamline the construction procurement process. In construction, procurements are often slow and cumbersome because many different stakeholders are involved in the process, including architects, engineers, contractors, and suppliers. With blockchain technology, all stakeholders would be able to view the digital ledger and see the procurement status.
- *Disputes:* Disputes in organizations with multiple stakeholders are inevitable. In a competitive environment such as construction, there are potential conflicts between participants whose views and benefits are different. Claims, which are inevitable in construction projects, turn into disputes unless managed. Disputes are rooted in three general fields: payment, document, and collaboration. BCT can manage various systems challenges by offering decentralization, security, and transparency.
- *Supply Chain Management:* The construction industry is known to have complex, lengthy, and network-based supply chains with a vast range of internal and external stakeholders. The prevailing practices in construction supply chain management are characterized by significant challenges, including fragmentation, a lack of trust among stakeholders, and restricted information sharing. By offering a transparent and secure platform for tracking the movement of products and resources, blockchain can improve supply chain management in the construction industry. The blockchain can be used to record every transaction and movement of products, allowing participants to track the origin, location, and status of items in real-time.
- *Transparency and Traceability:* Blockchain is a distributed ledger that will retain a permanent, tamperproof transaction record, which is one of its main advantages for real estate. Should the transaction ledger be shared across the entire industry network, it will promote transparency and help minimize mistrust among industry players, speeding up the whole transaction process. Construction professionals gravitate towards blockchain technology because of the benefits of transparency. Transparency may be

regarded as a blockchain that orders and sends transactions to all members in an apparent manner. Throughout the construction process, transparency and traceability are made possible via distributed ledger technology on the blockchain. As a result of the blockchain's ability to record every transaction, alteration, and update and make them accessible to authorized users, there is less room for fraud and manipulation.

- *Quality Control:* By offering a visible and unchangeable record of inspections, testing, and certifications, blockchain technology can improve quality control and certification procedures in the construction industry. The blockchain can securely record all pertinent data, including test results, compliance documentation, and the materials utilized. This guarantees that quality requirements are met. Quality control software standardizes quality control processes and ensures compliance with regulations and standards,
- *Data Immutability:* Data recorded in a blockchain are considered unchangeable, which is referred to as the immutability of the blockchain. The immutability of BCT can provide significant benefits to the construction industry by improving accountability, supply chain management, and regulatory compliance. The chances of fraud are reduced due to the blockchain's immutability. With the immutability of blockchain, data integrity, which plays an important role, can also be easily achieved.

BENEFITS

Since BCT platforms are decentralized, reducing unnecessary bureaucracy will improve open communications, and BCT application can prevent disputes rooted in communication issues, inaccurate documentation, and payment problems. The construction sector can overcome long-standing obstacles, boost production, and complete projects more successfully in the digital era by embracing blockchain. Other benefits include [2]:

- *Security:* This is an important aspect of blockchain technology. It is very challenging for hackers to tamper with the data kept on the blockchain because of the decentralized architecture of the network and the usage of cryptographic algorithms. The network is very resistant to fraud and criminal activity since consensus procedures are used to verify that everyone using it agrees on the authenticity of transactions.
- *Secure Storage:* Traditional methods of storing information involved a central repository from

which data could be accessed from anywhere. This method is always prone to security attacks, that could alter or tamper with the transaction statements from the central repository. For critical construction data, blockchain offers a safe and decentralized storage solution. Blockchain disperses data among numerous nodes, making it highly resistant to illegal access or manipulation. The system for safe data transfer and storage improves privacy and security. Unlike traditional storage methods, which provide a central repository (particularly subject to security attacks) from which data can be accessed from anywhere, the Blockchain is based on the creation of a distributed virtual distributed virtual register (tamper-proof), in which data is shared, stored and verified by the who manage the register in chronological order and without the need for an intermediary.

- *Anti-Fraud Measures:* The transparency and immutability of blockchain serve as effective barriers against fraud in the building sector. The blockchain keeps track of every transaction and modification, making it more difficult for bad actors to modify data or carry out fraudulent activities.
- *Project Tracking:* Project milestones, tasks, and resources may be accurately tracked because of the blockchain's transparency and audibility. Better project control, on-time delivery, and increased overall performance are all results of this improved project tracking.
- *Transparency and Trust:* The capacity of blockchain in construction to promote transparency and trust among all stakeholders is one of the most important advantages of this technology in the building industry. Blockchain in construction generates an immutable and transparent ledger of transactions in a typically fragmented business where information transmission is frequently time-consuming.
- *Reduced Fraud:* Blockchain technology for construction minimizes the fraud risk and transparency issues by introducing a decentralized, tamper-proof ledger system. In other words, the tamper-proof and secure nature of blockchain considerably lowers the chance of fraud and disagreements. Due to the cryptographical links between records kept on the blockchain in construction, it is very difficult to alter or corrupt data without being noticed. This quality is especially important in the construction industry, where disagreements frequently develop

around project milestones, payments, and quality control.

- *Improved Efficiency:* The paperwork-heavy procedures common in the construction sector are known to cause delays, mistakes, and inefficiencies. The automated and digital method of blockchain in construction streamlines the paperwork procedure. This shortens project times, decreases errors, and reduces administrative burden.
- *Modernized Contracts:* Blockchain changes the way of contract management in construction. It uses smart contracts that automatically carry out agreed-upon terms, cutting out the middleman. This automation makes sure that payments and deliveries only happen when certain conditions are met. It makes contracts more secure and efficient.
- *Increased Accountability:* Blockchain introduces a new level of responsibility in construction. Everyone involved gets access to the same unchangeable data, ensuring each party is held accountable for their actions. It leads to a more honest and responsible way of implementing construction projects.

Some of these benefits are illustrated in Figure 11 [9].

CHALLENGES

Blockchain adoption in the construction industry is not without its challenges. Productivity within the construction industry is adversely affected by traditional contracting arrangements, with frequent suspicion and mistrust among collaborative partners and stakeholders. To achieve successful adoption of BCT in construction, a number of obstacles and factors must be taken into account. Obstacles that must be overcome include technological infrastructure, data privacy and security issues, and the requirement for industry-wide collaboration. Trust and transparency, cost overruns, complex operational management, fragmentation, payment delays, and on-time project completion are some of the other challenges facing the industry. Some of these challenges are explained as follows [2]:

- *Resistance to Change:* The construction industry has traditionally been very reluctant to change and rather slow in adopting new digitization technologies. It can be difficult to persuade stakeholders to invest in this technology, particularly if they are used to conventional approaches. It is essential to show the long-term advantages and return on investment in order to get over change resistance.

- *Cost:* In order to implement blockchain, there is a variety of complex systems that will likely need to be created. This comes at a cost, both for the systems and to hire the people necessary to create and implement them. Implementing blockchain technology can involve a significant upfront cost. This comprises the cost of data migration, development, integration, and training. The costs for new hardware, software, and training can add up quickly. Thus, it becomes hard for smaller companies to afford these upgrades.
 - *Infrastructure:* To use blockchain, you need a strong tech setup, which many construction companies lack. Blockchain implementation in the building industry needs a strong technological foundation that can support the dispersed nature of the technology. The construction businesses must make sure they have the requisite hardware, network capabilities, and technical know-how to manage the demands of blockchain implementation.
 - *Data Privacy and Security:* In a world where data is generated in quintillions every single day, data privacy has become a major concern. Blockchain goes a long way in addressing this issue. Given that the construction business deals with sensitive information and intellectual property, data privacy and security are major issues. Sensitive data is used in construction projects, such as confidential financial information and private designs. Blockchain technology enhances security through encryption and decentralization, but businesses must still take into account the privacy implications and make sure they are in compliance with all applicable laws. The cryptographic encryption used by blockchains improves data security by ensuring that private data is shielded from unauthorized access.
 - *Collaboration:* Architects, engineers, contractors, and clients may communicate securely using blockchain-based collaboration tools. Blockchain improves cooperation, minimizes communication gaps, and promotes effective decision-making by offering a shared workspace for information exchange. Collaboration is necessary for the successful deployment of blockchain in the construction industry.
 - *Standardization:* For best practices to be established across the sector and to encourage wider adoption, collaboration, and standardization efforts are essential. Standardization promotes widespread usage of blockchain technology in the construction industry and facilitates frictionless data interchange while increasing transparency.
- To create industry-wide standards, protocols, and governance models, coordination is required between construction businesses, technology providers, and regulatory organizations.
- *Legacy Systems:* Integration with existing systems and procedures is one of the main obstacles to using blockchain in construction. It can be challenging to modify blockchain in construction so that it can live with legacy systems while maintaining data compatibility and consistency. The creation of interoperability standards, careful planning, and customization are all necessary for seamless integration.
 - *Scalability:* As you add more to a blockchain, it can slow down, becoming less efficient, especially for big projects where speed is key. Blockchain networks may experience scalability problems as more transactions are processed. Making sure the blockchain in construction can manage a lot of transactions at once is essential for the construction industry, which has many participants and generates a lot of data.
 - *Sustainability:* Environmental concerns have also been raised by the energy consumption of blockchain networks, particularly proof-of-work-based systems. Sustainable blockchain adoption necessitates actions to address scalability and reduce energy consumption.
 - *Legislation:* The idea of using blockchain is one thing, but the very process of integrating it into various industries is a different thing altogether. Lawmakers are yet to introduce legislation to make what happens on the blockchain legally binding. A lack of such legislation will hinder blockchain adoption across various industries. Legislation is required to create proper functioning of smart contracts and to govern how disputes relating to such contracts will be resolved.
 - *Regulation:* The decentralized nature of blockchain puts the established legal and regulatory systems to the test. An intricate web of laws, agreements, and compliance requirements governs the construction business. It might be challenging to implement blockchain systems that are compatible with current regulatory frameworks and guarantee security and transparency.
 - *Enhanced Transparency:* Blockchain brings unmatched clarity to construction projects. It records every action, from buying materials to signing contracts, on a secure, unchangeable ledger. This clarity cuts down the risk of fraud

and poor management. As a result, stakeholders investing in these projects can be confident that their money is being used properly.

Figure 12 Some of the challenges and limitations of blockchain in construction [16].

CONCLUSION

Blockchain technology is among the most disruptive forces of the past decade. Its adoption is a trend that will help the construction industry become more efficient overall. The development of blockchain technology offers the construction sector a hitherto unheard-of possibility. Construction businesses may improve supply chain efficiency, cut down on delays, and minimize risks by embracing the transparency and traceability offered by blockchain technology.

In recent years, blockchain technology has attracted momentous attention in the construction industry. BCT has a bright future in the construction sector and has the ability to significantly impact the sector. It is on track to make a big impact on the construction industry. It promises to make things more efficient, transparent, and cooperative. More information on the integration of blockchain technology into the construction industry is available from the books in [17-19] and in the following related journals:

- IEEE Blockchain
- Construction Magazine
- Buildings
- Journal of Building Engineering
- Journal of Construction Engineering and Management

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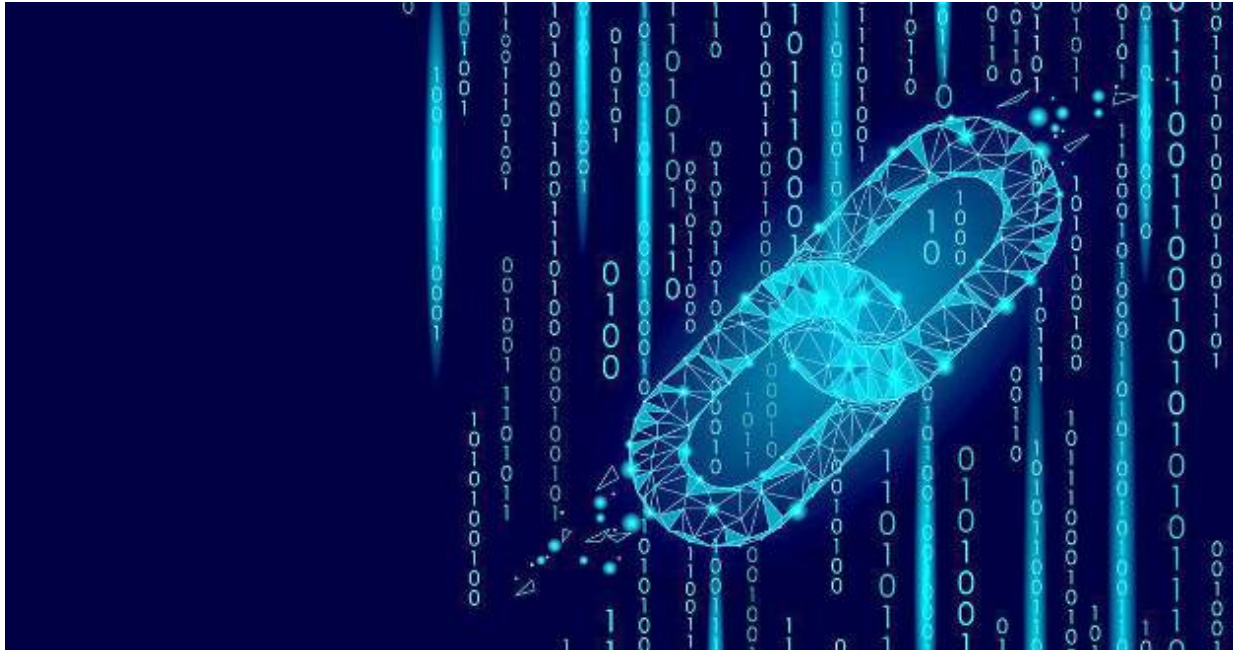


Figure 1 The symbol of blockchain [1].



Figure 2 A typical construction site [2].



Figure 3 Some construction workers [2].

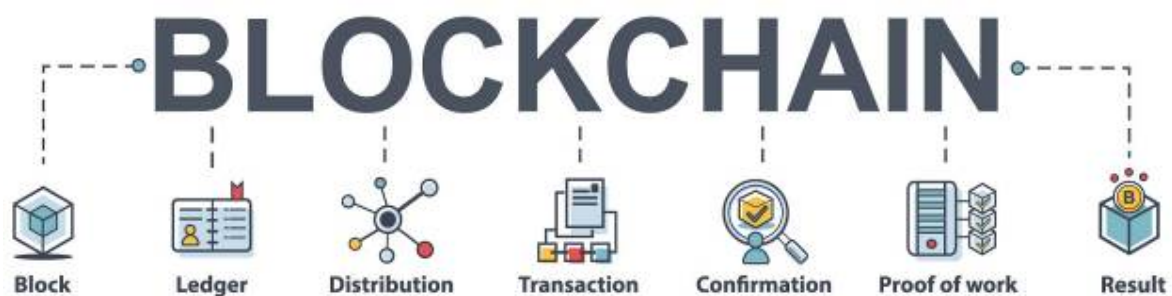


Figure 4 Different components of blockchain [6].

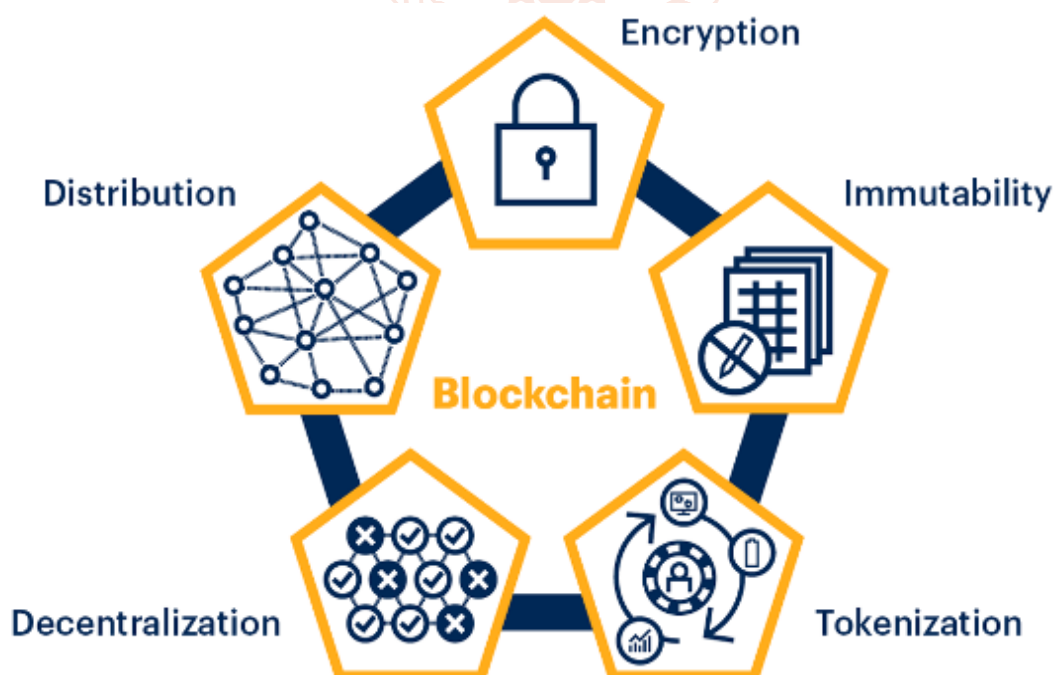


Figure 5 Five key elements of Blockchain [7].



Figure 6 Bitcoin [8].

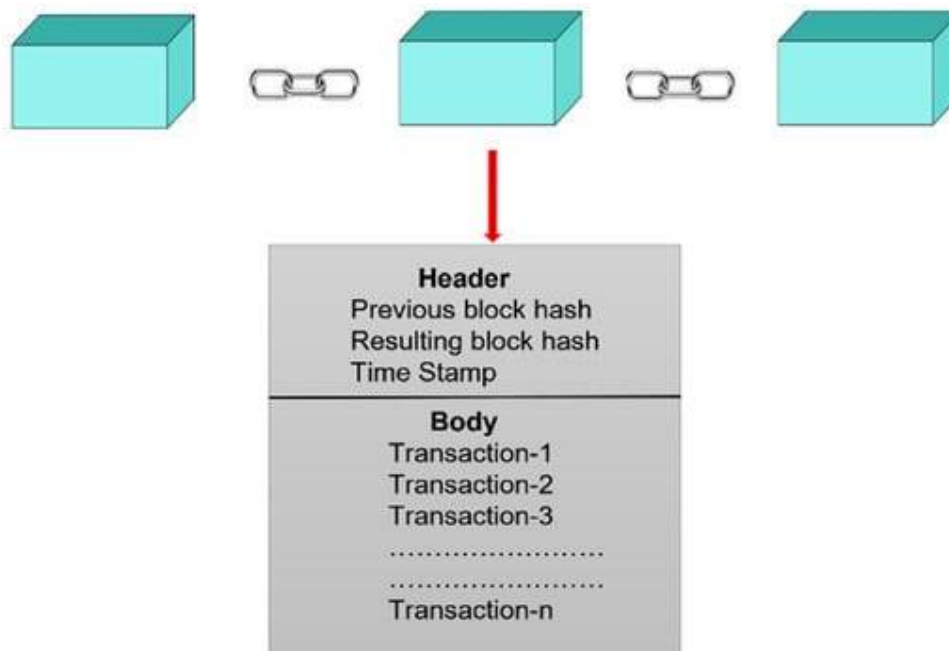


Figure 7 How blockchain works [9].

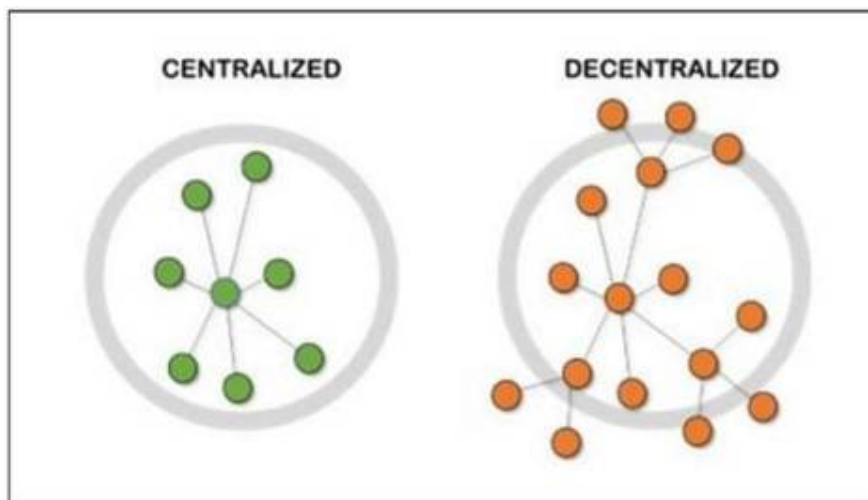


Figure 8 The decentralized property of blockchain [9].

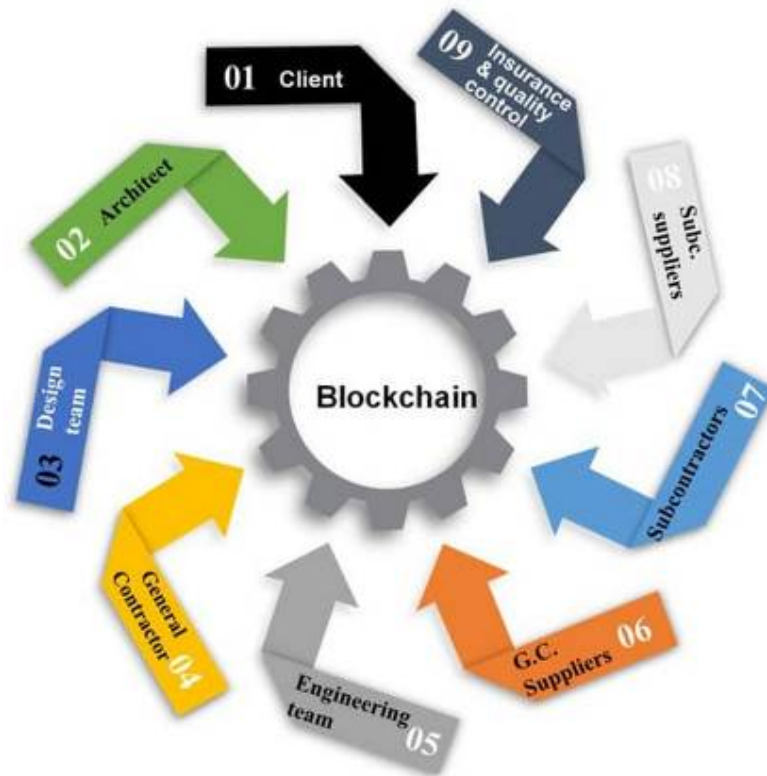


Figure 9 Blockchain in construction [12].

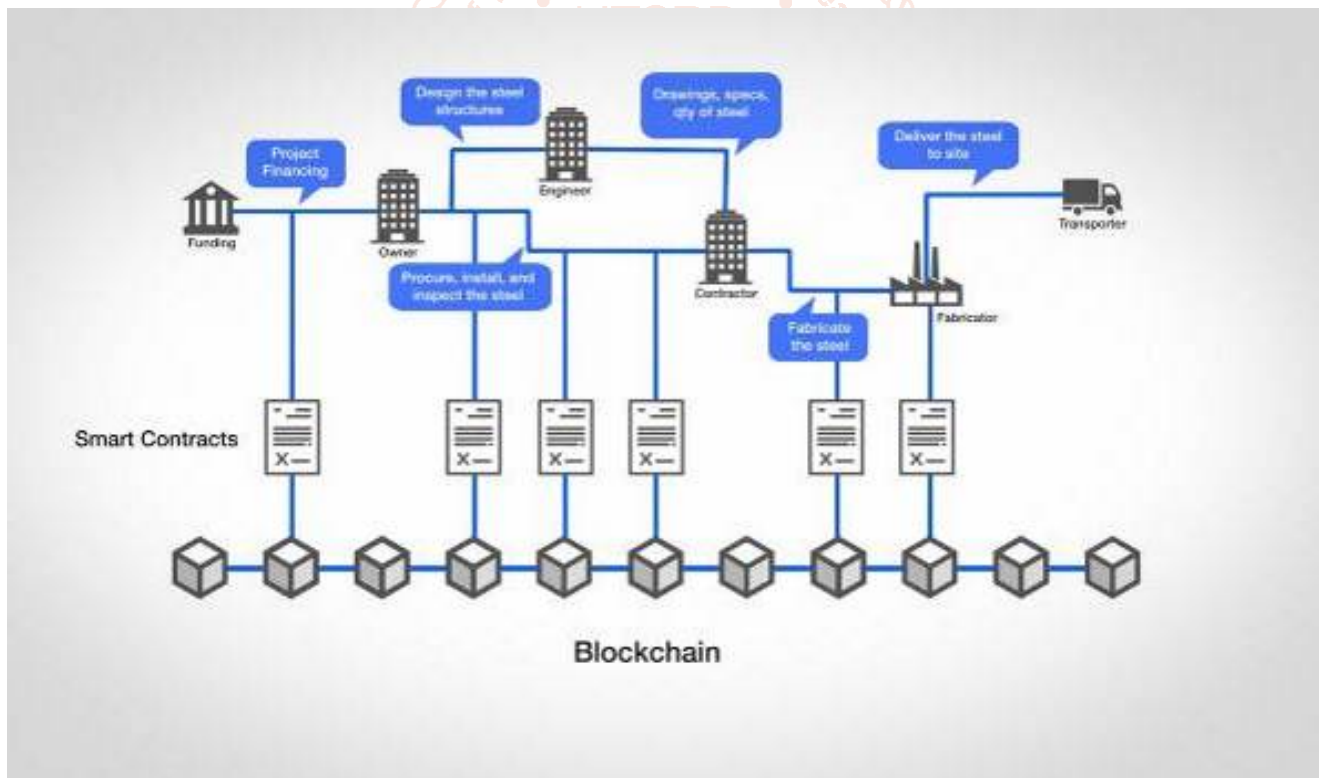


Figure 10 Smart contract [15].

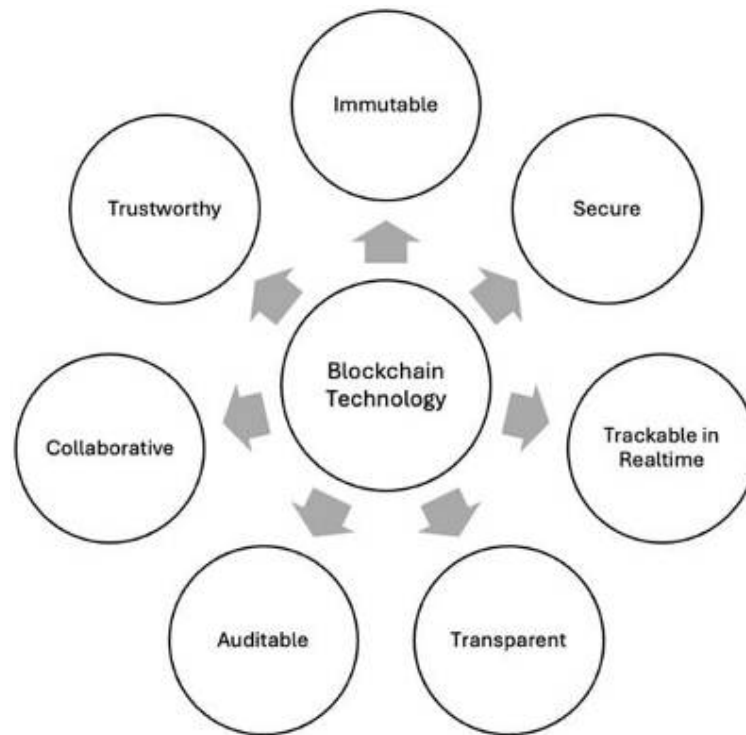


Figure 11 Some of the benefits of blockchain in construction [9].

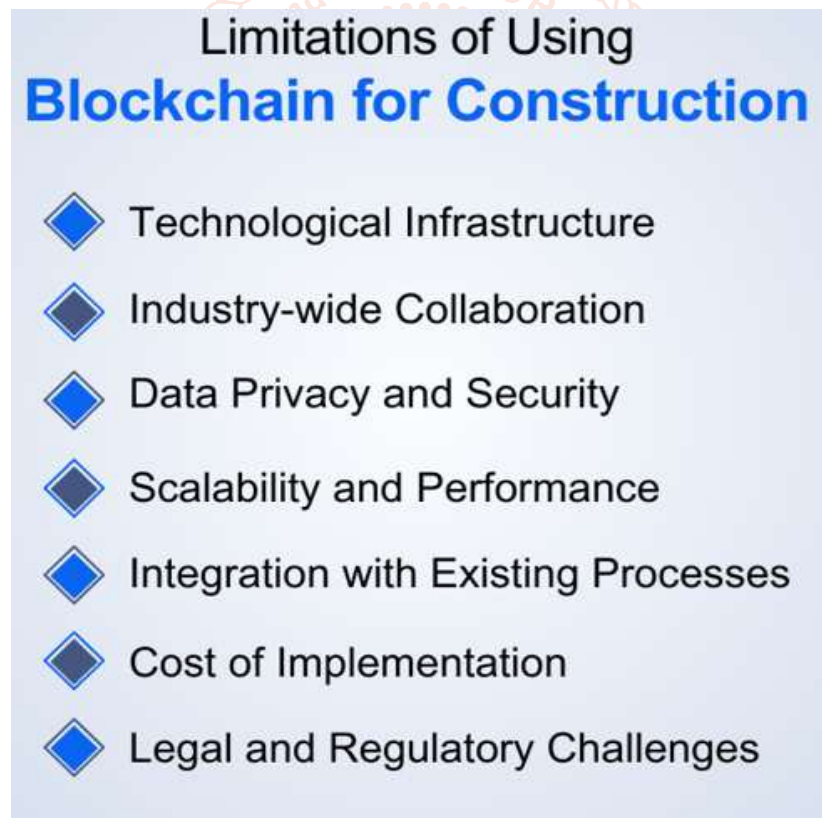


Figure 12 Some of the challenges and limitations of blockchain in construction [16].